1977-09-01

Land Use and Land Use Practices in the Great Lakes Basin: Report of the International Reference Group on Great Lakes Pollution from Land Use Activities: Joint Summary Report Task B, United States and Canada

International Reference Group on Great Lakes Pollution from Land Use Activities

INTERNATIONAL REFERENCE GROUP ON GREAT LAKES POLLUTION FROM LAND USE ACTIVITIES

INTERNATIONAL JOINT COMMISSION

LAND USE AND LAND USE PRACTICES IN THE GREAT LAKES BASIN

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REPORT OF THE
INTERNATIONAL REFERENCE GROUP
ON GREAT LAKES POLLUTION
FROM LAND USE ACTIVITIES

JOINT SUMMARY REPORT - TASK B
UNITED STATES AND CANADA

SEPTEMBER 1977

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PREFACE

This report presents a summary of an Inventory of Land Use and Land Use Practices in the Great Lakes Basin, including trends and projections to 1980, and to 2020 where appropriate. It contains the important features of the Canadian and United States reports on land inventory prepared by the International Reference Group on Great Lakes Pollution from Land Use Activities.

Land uses are broken down for each Lake Basin as follows:

- Area (Land and Water)
- Residential
- Commercial - Industrial
- Cropland
- Pasture
- Forest
- Outdoor Recreation
- Wetlands
- Barren
- Water (Inland)

In addition, eight specialized land use categories are discussed and units quantified:

- Mine Tailings Disposal Areas
- Liquid and Solid Waste Disposal Areas
- Dredge Spoil Disposal
- Deepwell Disposal
- Lakeshore and Riverbank Erosion
- Intensive Livestock Operations
- High Density Non-sewered Areas
- Recreational Lands

Annual materials usages are presented for:

- Agricultural Pesticides
- Commercial Fertilizers
- Agricultural Manures
- Lime
- Road Salt.

For more detailed information, one should refer to the reports prepared for the United States part of the Great Lakes Basin which is contained in six volumes and the Canadian counterpart which consists of five volumes. These reports are available from the International Joint Commission's Great Lakes Regional Office, Windsor.

INTRODUCTION

The Great Lakes Water Quality Agreement, with Annexes, Texts and Terms of Reference between the United States of America and Canada, signed at Ottawa on April 15, 1972, included a reference to study pollution in the Great Lakes System from agriculture, forestry, and other land use activities. The reference asked that the study assess whether the boundary waters of the Great Lakes System were being polluted by land drainage and, if so, where and to what extent and what remedial measures would provide improvements in controlling pollutants from land usage. Accordingly, the International Reference Group on Great Lakes Pollution from Land Use Activities was established in late 1972, and produced a detailed study plan (February, 1974) outlining an extensive study scheduled for completion by mid 1977 with a final report in July 1978.

The Reference Group established four task groups to examine various aspects of the problem. These Task groups were directed to:

Task A. To assess problems, management programs and research and attempt to set priorities in relation to the best information now available on the effects of land use activities on water quality in boundary waters of the Great Lakes.

Task B. Inventory of land use and land use practices, with emphasis on certain trends and projections to 1980 and, if possible, to 2020. Present land use report to be completed in 1974, report on trends to be completed in 1975.

Task C. Intensive studies of a small number of representative watersheds, selected and conducted to permit some extrapolation of data to the entire Great Lakes basin and to relate contamination of water quality, which may be found at river mouths on the Great Lakes, to specific land uses and practices. Preparation of activities in 1974, intensive surveys in 1975 and 1976.

Task D. Diagnosis of degree of impairment of water quality in the Great Lakes, including assessment of concentrations of contaminants of concern in sediments, fish and other aquatic resources. Activities during 1974 - 1976.

The purpose of the land use inventory and projections was to serve as the basis for extrapolating the data from the pilot watershed studies to the entire Basin in order to quantify loadings and identify and rank contributing areas and land uses.

The objectives of this activity were directed towards the following subject areas:

(1) provision of a general land use inventory of the Great Lakes Basin

(2) provision of specific information concerning the nature and location of defined specialized land use categories in the Great Lakes Basin.

(3) provision of information on the physical fabric of the Great Lakes Basin including soils and their capability, hydrology, geomorphology, climate, mineral and gas resources, and broad vegetation zones.

(4) provision of an inventory of various materials applied to land which may influence the quality of drainage waters

(5) provision of a consistent and comprehensive set of projections for 1980 and 2020 relating to land uses and land use activities based upon socioeconomic, technological and political development.

PHYSICAL AND SOCIAL FABRIC

Physical fabric information considered important to land drainage/ water quality relationships includes geology, soils, minerals, climate, surface and ground water, and vegetation and wildlife. Demographic and economic characteristics were also considered as they relate to the human adaptation and use of the physical environment.

The Great Lakes Basin

The Great Lakes Basin is one of the largest and most rapidly growing industrial and urban complexes in the world, containing 14 percent of the population of the United States and 33 percent of the population of Canada. The basin of the Great Lakes System extends more than 1600 kilometres (1000 miles) inland from the Atlantic ocean into the heart of the North American continent. It includes 463,900 square kilometres (178,000 square miles) of the United States and 321,500 square kilometres (124,000 square miles) of Canada (Table 1), for a total area of 785,400 square kilometres, comprising parts of eight states of the United States, (including virtually all of Michigan), and one-third of the area of the Canadian province of Ontario.

The drainage and political divisions of the Great Lakes basin are shown in Figure 1.

Land Resources

The bedrock and glacial geology of the Great Lakes basin are illustrated in Figures 2 and 3 respectively. The basin is underlain almost entirely by a thick succession of sedimentary rocks. Glacial and alluvial deposits cover the bedrock, and topography is irregular and varied, including depressions occupied by small lakes or marshes, level to sloping plains, and low rolling hills or ridges. Three major physiographic regions are present (Figure 4): the Laurentian Uplands; the Interior Lowlands; and the Appalachian Plateau. The soils of the basin vary by area and reflect past and present climatic conditions, natural drainage, vegetative cover, and time interacting with parent glacial materials. The mineral industry is important to local and national economies. Occurrence and production of the mineral resources depend on the geographic distribution and accessibility of certain formations.

TABLE 1

GREAT LAKES AREA MEASUREMENT (SQUARE KILOMETRES)*

	DRAINAGE BASIN (land and water)			WATER SURFACE			LAND SURFACE		
	U.S.	CANADA	TOTAL	U.S.	CANADA	TOTAL	U.S.	CANADA	TOTAL
LAKE SUPERIOR	97,500	113,100	210,600	53,600	28,900	82,500	43,900	84,200	128,100
LAKE MICHIGAN	176,600	0	176,600	58,000	0	58,000	118,600	0	118,600
LAKE HURON	65,800	128,700	194,500	23,700	36,100	59,800	42,100	92,600	134,700
LAKE ERIE	67,600	36,500	104,100	13,400	13,500	26,900	54,200	23,000	77,200
LAKE ONTARIO	56,400	43,200	99,600	9,300	10,400	19,700	47,100	32,800	79,900
TOTAL BASIN STUDY AREA	463,900	321,500	785,400	158,000	88,900	246,900	305,900	232,600	538,500

* To convert from square kilometres to square miles, multiply by 0.3861

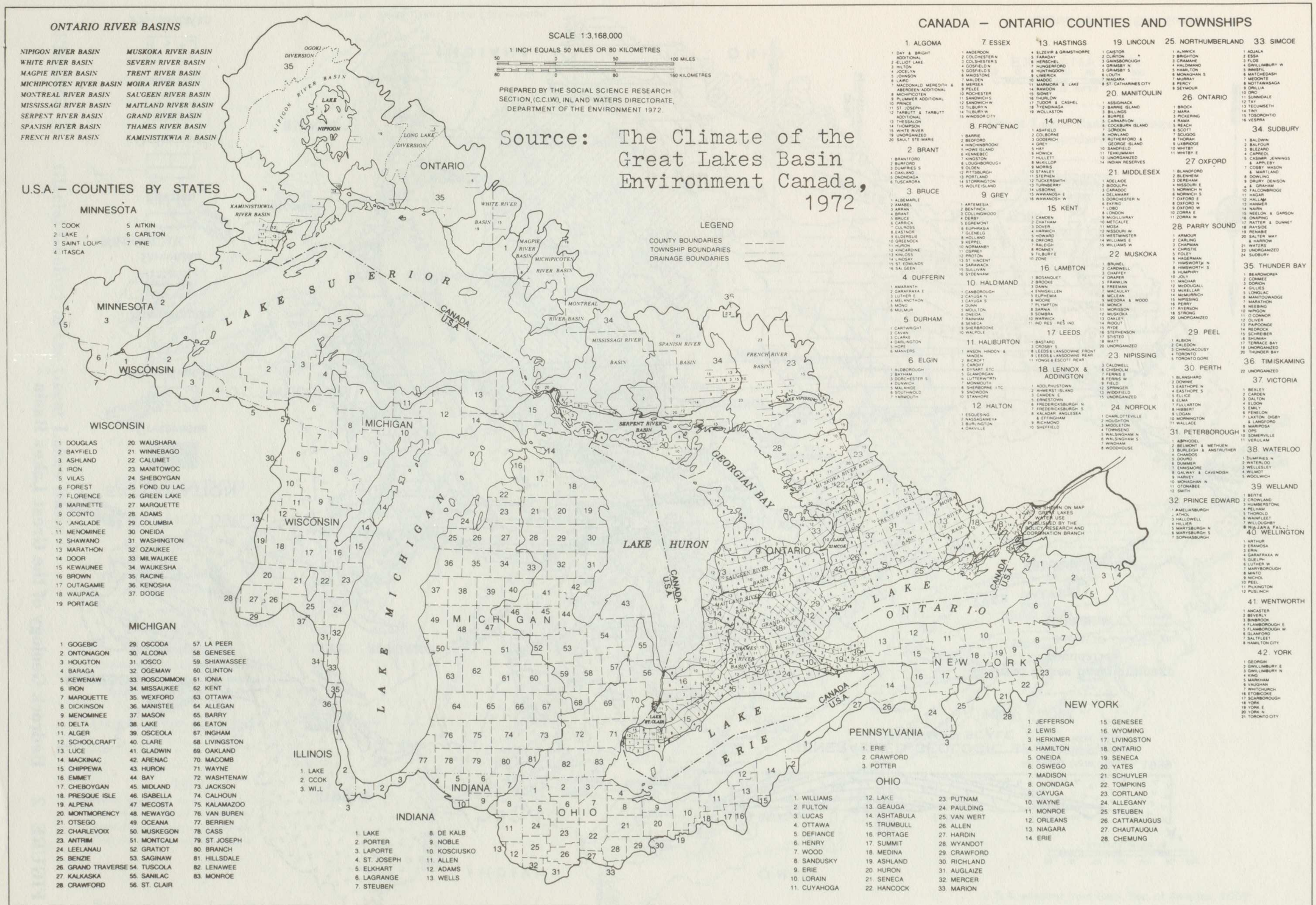


FIGURE I GREAT LAKES BASIN DRAINAGE AND POLITICAL DIVISIONS

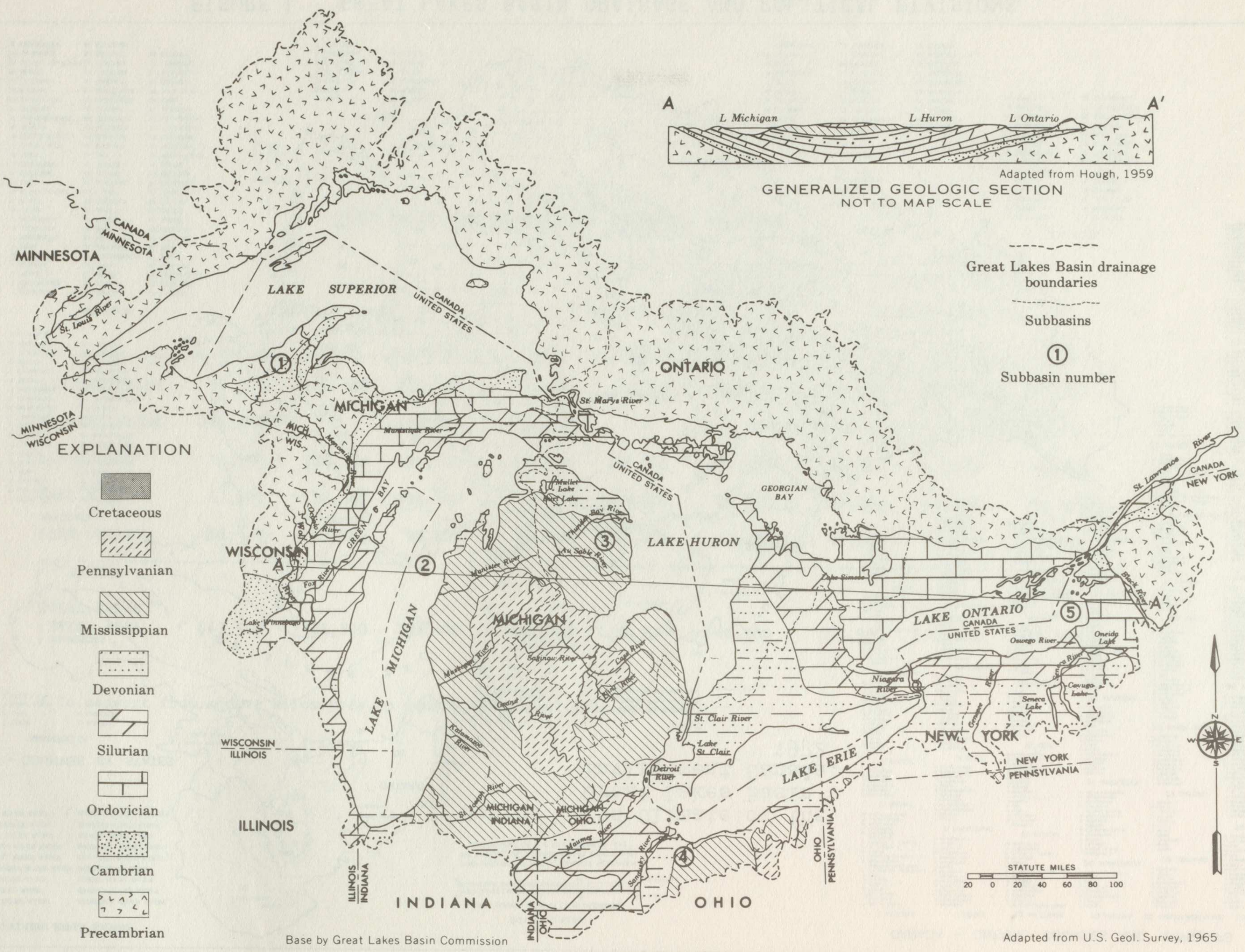
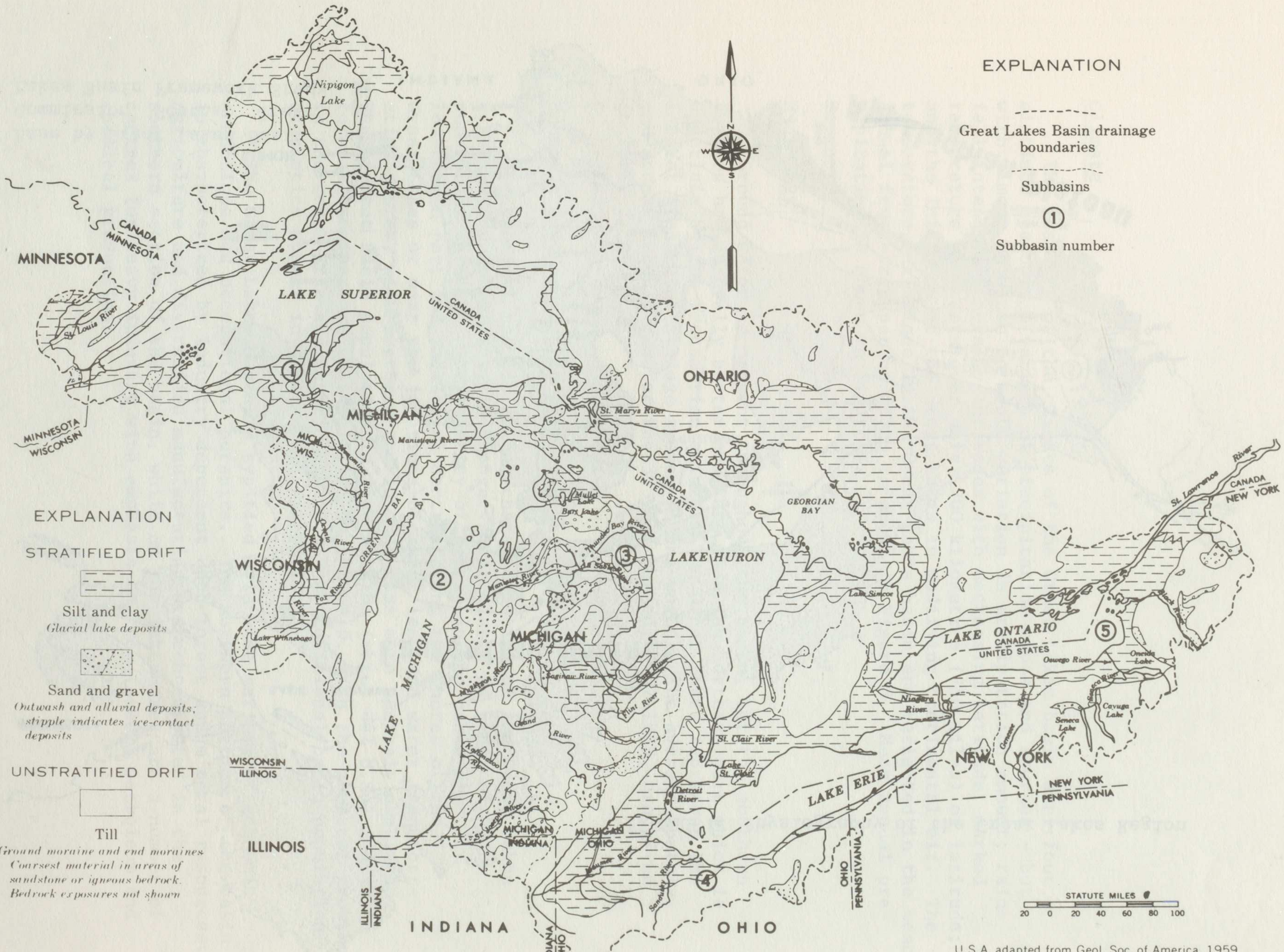


FIGURE 2 Bedrock Geology of the Great Lakes Basin[2]

FIGURE 3 Glacial Geology of the Great Lakes Basin [2]

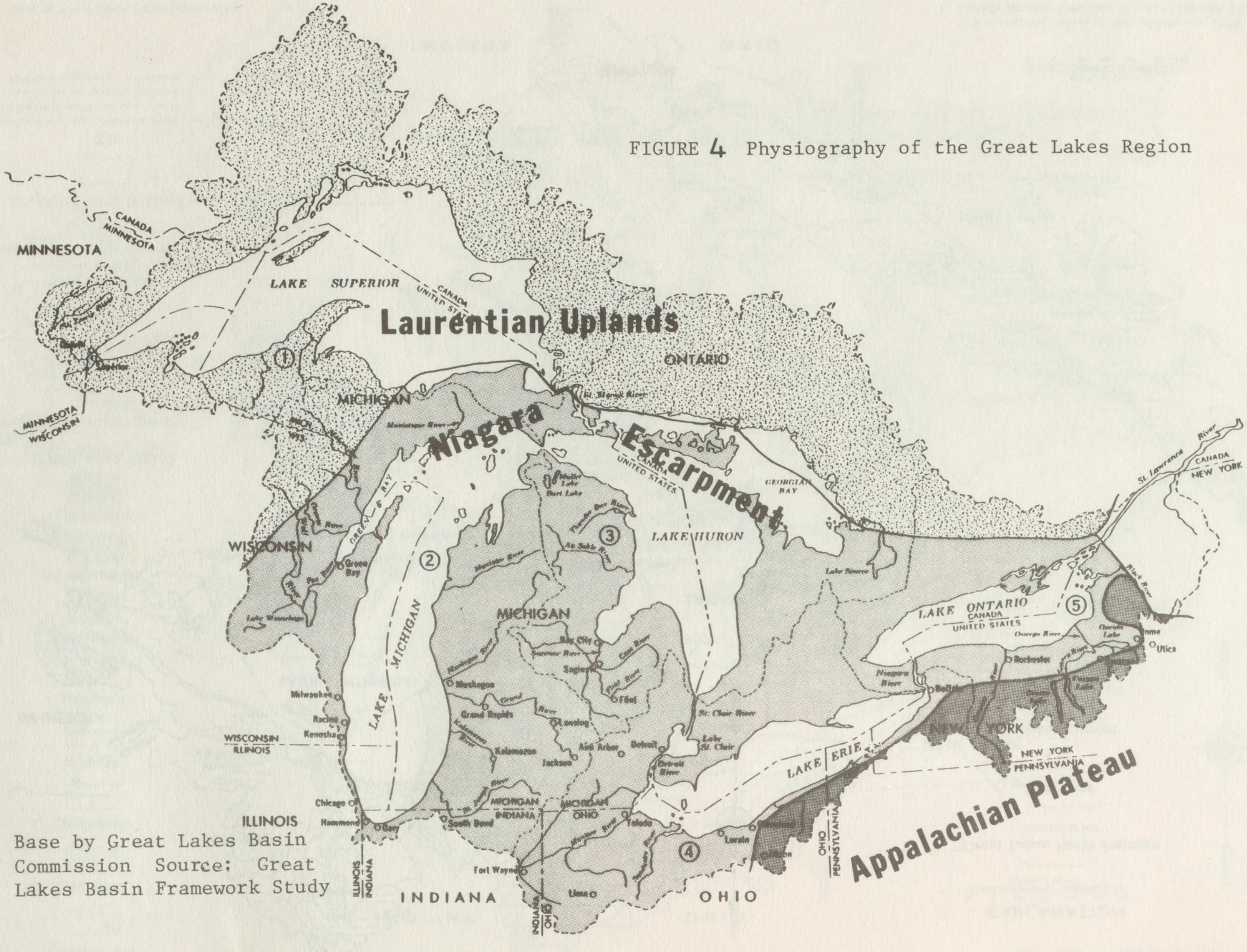


Base by Great Lakes Basin Commission

Source: Great Lakes Basin Framework Study

U.S.A. adapted from Geol. Soc. of America, 1959
Canada adapted from Geol. Survey of Canada, 1968

FIGURE 4 Physiography of the Great Lakes Region



Base by Great Lakes Basin Commission Source: Great Lakes Basin Framework Study

Climate

The features of the climate of the Great Lakes basin are: four distinct seasons; a variety of precipitation types and sources - but with almost no month to month variation in precipitation amount; rainfall intensity generally increases with decreasing latitude; marked temperature contrasts over only 1200 kilometres (750 miles) of latitude; and the influence of the Great Lakes in modifying continental air. The temperature variations in the Great Lakes basin are reflected in the mean annual frost-free period which is shown in Figure 5. Mean annual precipitation is shown in Figure 6.

Hydrology

Ground water is present throughout the basin, but the southern portion has generally better aquifers than the northern part which is underlain by the Precambrian shield. The Great Lakes represent the largest freshwater storage system in the world. The average monthly and annual lake levels for the 33 year period, 1937-1969, are given in Table 2.

Economic and Demographic Characteristics

The chemical and biological characteristics of the Great Lakes system are undergoing rapid change, particularly in areas of high population density. The majority of people in the basin are located in port and industrial centres along the shores of the Great Lakes or near the junctions of major land and water transportation routes, with northern and inland areas more sparsely populated. The present Basin population is 35.6 million (about 84% U.S.) and is forecast to increase to 54 million by 2020 A.D. with the greatest growth in the Lakes Erie and Ontario Basins. Some additional basin population statistics appear in Table 3 and Figure 7.

The Great Lakes basin is typified by a wide variety of economic conditions and occupational pursuits. The northern portion of the basin is characterized by industry dependent upon forest and mineral resources. Agriculture and diversified manufacturing are concentrated in the southern section of the basin, while on the lakeshores are a number of centres for heavy industry with emphasis on iron, steel, petroleum and chemical production.

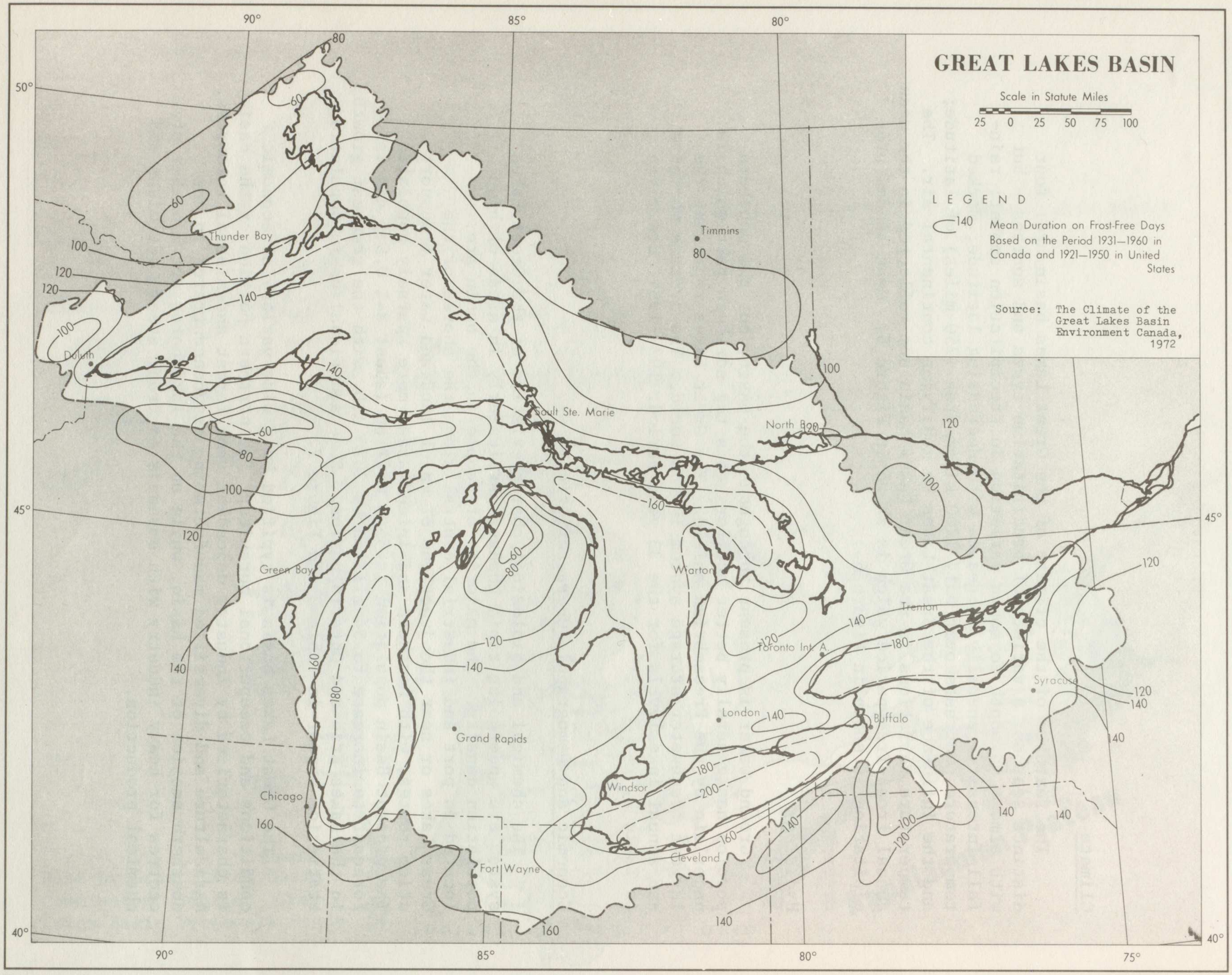


Figure 5 **MEAN ANNUAL FROST-FREE PERIOD (DAYS).** Along the lakeshore frost-free periods are 1 to 2 months longer in duration than inland. The frost-free season is longest, about 200 days, along the south shore of Lake Erie. The shortest frost-free duration is found in upland areas away from the lakes, i.e. less than 80 days in the Menominee Range of northern Michigan and Wisconsin and in Ontario north and east of Lake Nipigon. Stations located in "frost hollows" can experience frost at any time during the year.

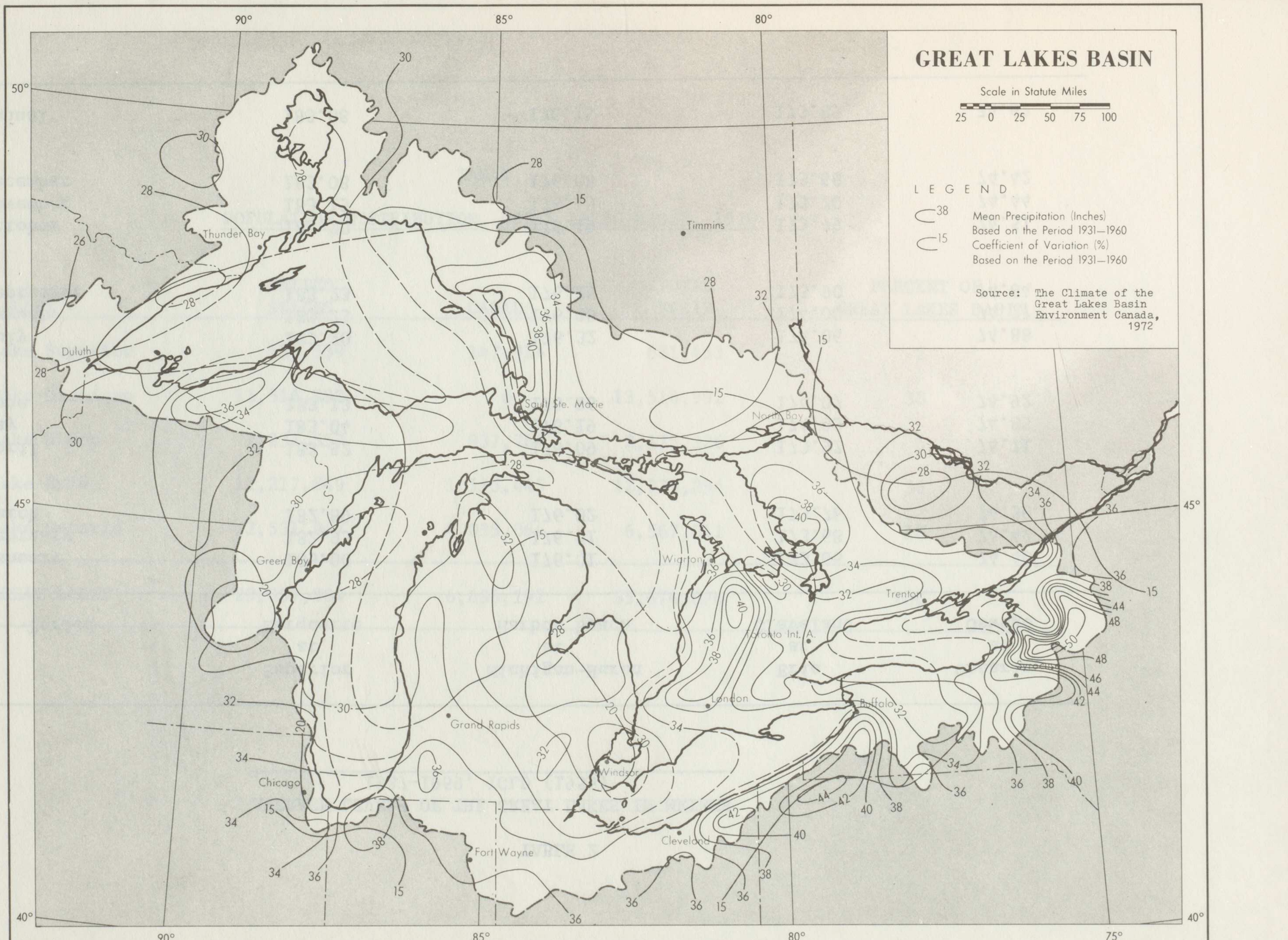


Fig. 6 – **MEAN ANNUAL PRECIPITATION (INCHES) AND ITS COEFFICIENT OF VARIATION (%).** Precipitation increases southeastward from a low of 28 inches in Minnesota to a high of 52 inches in the Adirondacks of New York state. Other smaller maxima may result from urban effects and topographic control on the leeward side of the Great Lakes, where the water equivalent of winter precipitation may exceed summer rainfall. The coefficient of variation is small averaging 15 per cent across the basin.

(Multiply all precipitation numbers by 2.5 to convert to cm.)

TABLE 2

AVERAGE LEVELS OF THE GREAT LAKES IN METRES
1937-1969, IGLD (1955)

Period	Superior at Marquette	Michigan-Huron at Harbor Beach	Erie at Cleveland	Ontario at Oswego
January	183.00	176.01	173.66	74.40
February	182.93	176.01	173.68	74.42
March	182.89	176.02	173.76	74.50
April	182.92	176.09	173.92	74.71
May	183.04	176.19	174.03	74.85
June	183.13	176.26	174.07	74.92
July	183.20	176.32	174.06	74.88
August	183.23	176.30	174.00	74.77
September	183.23	176.25	173.90	74.64
October	183.20	176.19	173.79	74.51
November	183.15	176.13	173.70	74.44
December	183.08	176.08	173.68	74.42
Annual	183.08	176.15	173.85	74.62

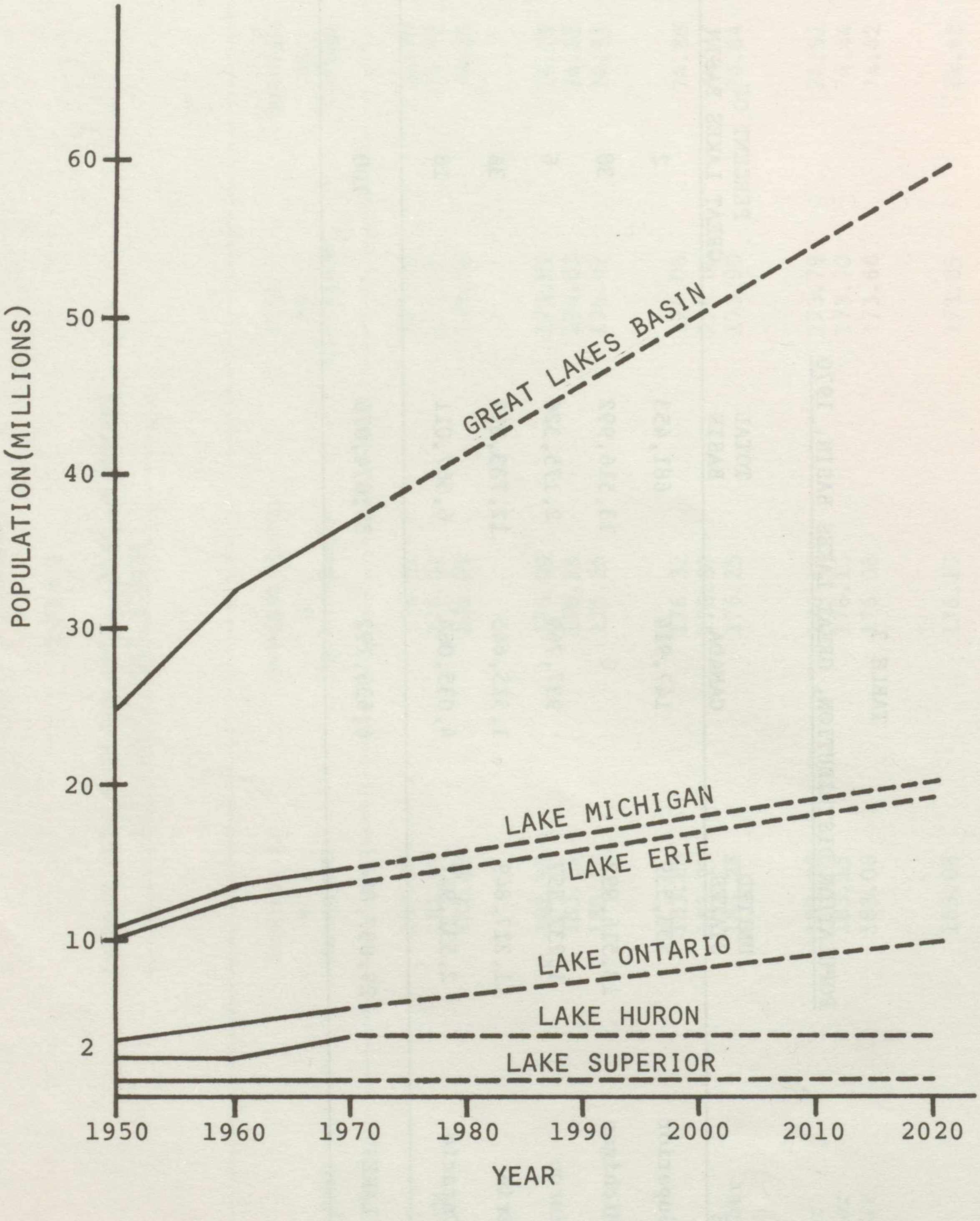
TABLE 3

POPULATION DISTRIBUTION, GREAT LAKES BASIN, 1970

LAKE	UNITED STATES	CANADA	TOTAL BASIN	PERCENT OF GREAT LAKES BASIN
Lake Superior	533,539	147,914	681,453	2
Lake Michigan	13,516,992	0	13,516,992	38
Lake Huron	1,237,557	937,769	2,175,326	6
Lake Erie	11,217,849	1,515,445	12,733,294	36
Lake Ontario	2,531,947	4,035,064	6,567,011	18
GREAT LAKES	29,037,884	6,636,192	35,674,076	100

FIGURE 7

POPULATION LEVELS 1950 TO 2020



both Canadian & U.S. ?
← Task B update after GLBC framework study includes both Canada & U.S.

Economic Trends

Future trends in the economic structure of the Canadian and United States portions of the Great Lakes basin are shown in Figures 8 and 9, respectively. The Canadian forecasts show land-based economic activities continuing their past decline as a share of total output. The contribution of agriculture, forestry, and fisheries to total output is projected to decline from 4.8 percent of the total in 1970 to about 3.8 percent in 2020. In contrast, the contribution of secondary industries (including mining, manufacturing, construction, transportation and utilities) is projected to increase from 51.3 percent in 1970 to 61.2 percent in 2020. The service industries contributed 44.1 percent in 1970; this is projected to fall to 34.9 percent in 2020.

In the United States projections, agriculture, forestry and fishery also decline as a share of total earnings. Manufacturing declines from 39 percent of the total earnings in 1970 to 30 percent in 2020. Earnings in the service sector will increase from about 14 percent of the total to 19 percent. Earnings in the government sector as a percentage of the total are projected to increase as well, from 12 percent in 1970 to 16 percent in 2020.

Vegetation and Wildlife

The natural vegetation of the Great Lakes basin has been greatly modified. Virgin forest lands are almost nonexistent, and much of the once-forested land, especially in the southern portions of the region, has been replaced by urban, industrial and agricultural development.

The varieties of wildlife that occupy the various classes of habitat are diverse, and include large game, waterfowl, shore birds, wading birds, song birds, small game and fur bearing animals.

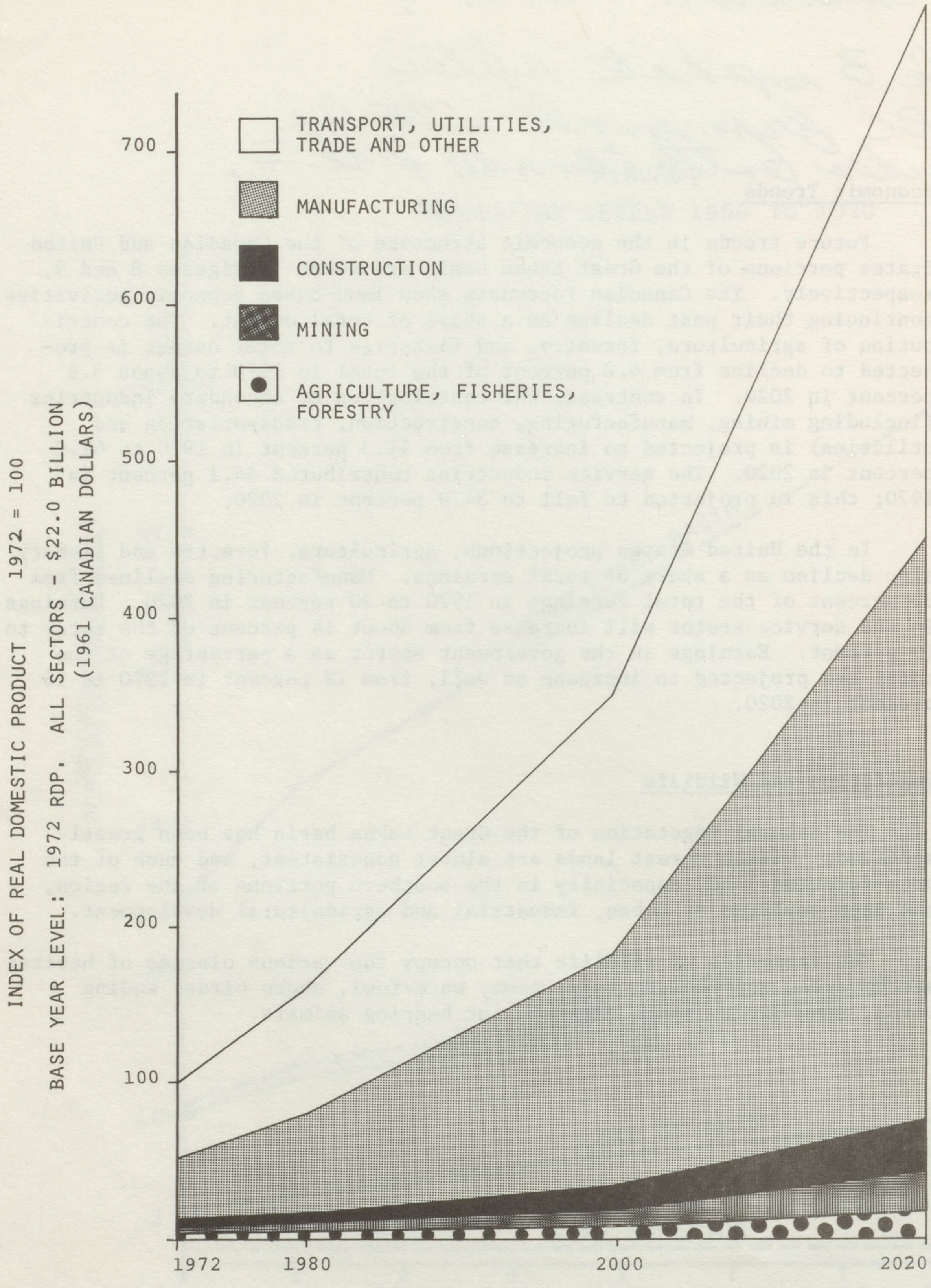


FIGURE 8 PROJECTED ECOMONIC STRUCTURE OF THE CANADIAN GREAT LAKES BASIN

SOURCE: C.A. SONNEN AND P.M. JACOBSON. 1974 CANADA.

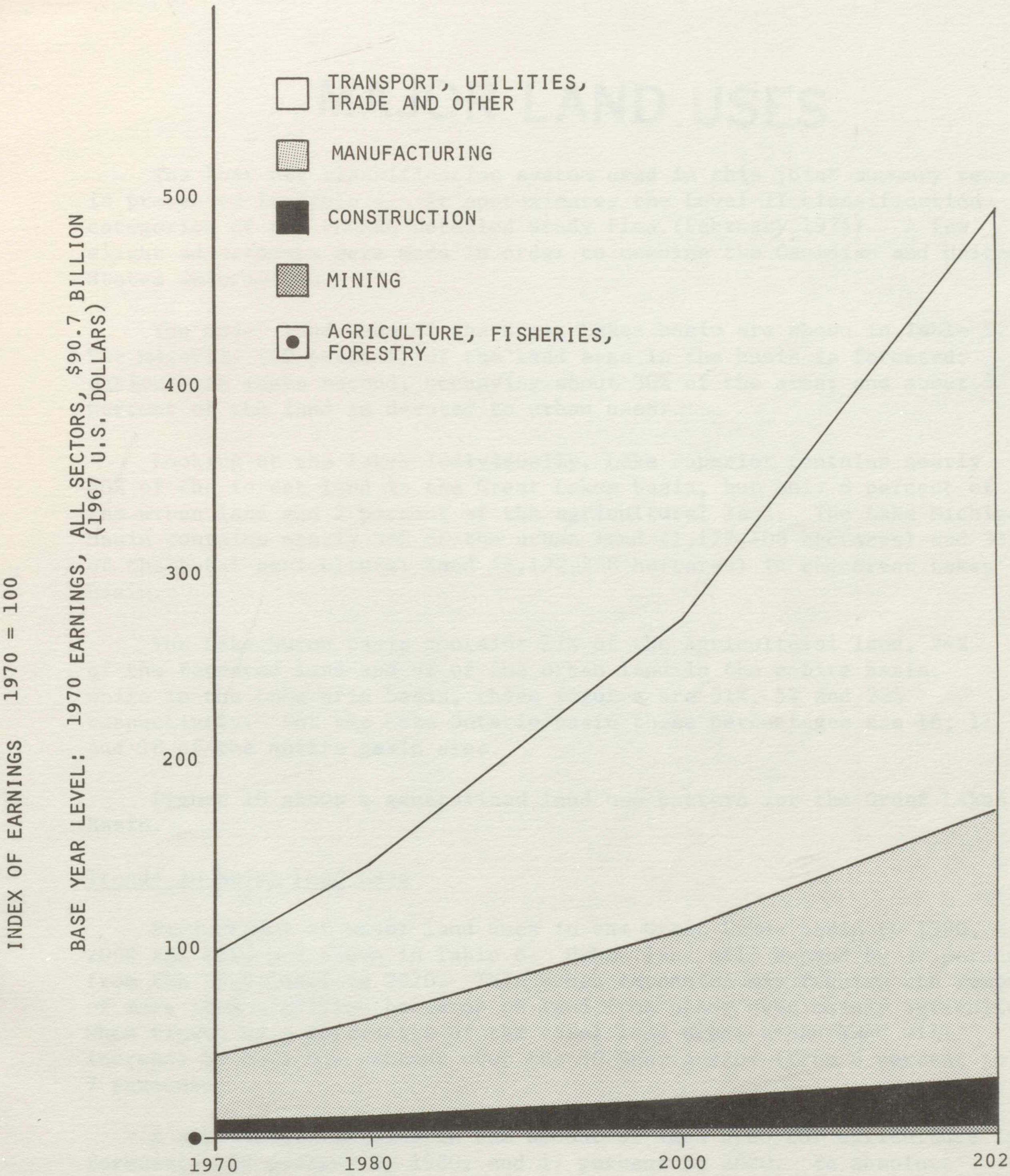


FIGURE 9 PROJECTED ECONOMIC STRUCTURE OF THE UNITED STATES GREAT LAKES BASIN

SOURCE: 1972 OBERS E. PROJECTION U.S.

MAJOR LAND USES

The land use classification system used in this joint summary report is presented in Table 4. It approximates the Level II classification categories of the PLUARG Detailed Study Plan (February 1974). A few slight adjustments were made in order to combine the Canadian and United States information.

The major land uses of the Great Lakes basin are shown in Table 5. The majority (60 percent) of the land area in the basin is forested; agriculture ranks second, occupying about 30% of the area; and about 5 percent of the land is devoted to urban uses.

Looking at the lakes individually, Lake Superior contains nearly 50% of the forest land in the Great Lakes basin, but only 8 percent of the urban land and 2 percent of the agricultural land. The Lake Michigan basin contains nearly 36% of the urban land (1,122,708 hectares) and 33% of the total agricultural land (6,122,268 hectares) in the Great Lakes Basin.

The Lake Huron basin contains 17% of the agricultural land, 24% of the forested land and 9% of the urban land in the entire Basin, while in the Lake Erie basin, these figures are 31%, 5% and 28% respectively. For the Lake Ontario basin these percentages are 16, 11 and 18 of the entire basin area.

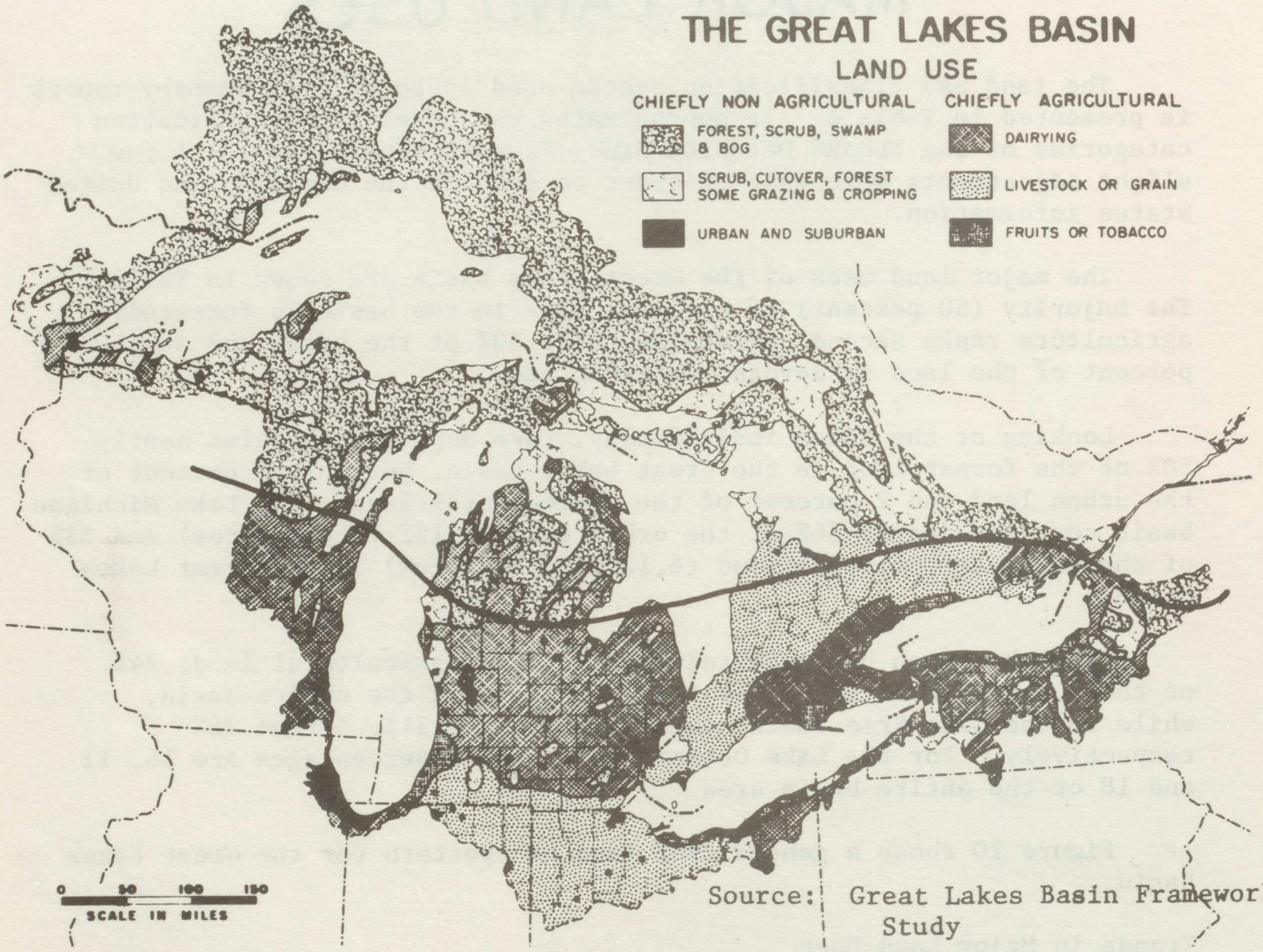
Figure 10 shows a generalized land use pattern for the Great Lakes Basin.

Trends in Major Land Uses

Projections of major land uses in the Great Lakes basin to 1980, 2000 and 2020 are shown in Table 6. Urban land will expand by 37 percent from the 1970 level to 2020. This urban expansion may require the removal of more than a million hectares of land from other uses mainly agriculture. When viewed as a percentage of the total land area, urban land will increase by only one percent over the 50 year period (from 6 percent to 7 percent).

A substantial decline in the amount of land used for agriculture is forecast: 12 percent by 1980; and 17 percent by 2020. In absolute terms, this is a loss of about three million hectares from 1970 to 2020.

The amount of forest land will remain about the same until 1980 and then decline by one percent by 2020.



Source: Great Lakes Basin Framework Study

FIGURE 10 Major Categories of Land Use in the Great Lakes Basin. Heavy line separates urban and agricultural land-use area from nonagricultural area.

TABLE 4 - LAND USE CLASSIFICATION CATEGORIES

Residential - land used for residential purposes. Single and multiple dwelling units in the built-up portions of cities and towns were included. Areas of urban sprawl, such as country estates and strip residential developments were also included.

Commercial - Industrial - land used for commercial, industrial, or institutional purposes. (Canadian data on transportation and extractive land uses were also included in this category).

Cropland - land used for the production of annual crops (row crops and close grown crops) and land used for orchards and vineyards.

Pasture - areas of more or less perennial grassland including permanent pastures, hayland, and areas of green manure crops.

Forest - land bearing forest, short trees or brush where the tree cover exceeds 25 percent (Canadian data) or 40 percent (U.S. data).

Outdoor Recreation - (available for Canadian portion only) - land used for private or public outdoor recreation.

Wetlands - marshes and swamps.

Barren - land which did not support vegetation (data available only for Canadian portion)

Water - any area of open water such as lakes, ponds, creeks, rivers, etc. (data available only for U.S. portion).

Note: The Canadian Land Use data were collected on the basis of a hydrologic basin and the U.S. data on the basis of planning sub-areas aggregated to approximate the basin.

TABLE 5

MAJOR LAND USES
GREAT LAKES BASIN
(Hectares)*

	URBAN		AGRICULTURE						
	RESIDENTIAL	COMMERCIAL INDUSTRIAL	CROP-LAND	PASTURE	FOREST	OUTDOOR RECREATION	WET-LAND	BARREN	WATER
LAKE SUPERIOR									
U.S.	138,872	95,416	10,604	389,924	5,512,240	-	315,160	-	398,296
Canada	5,959	3,687	2,241	51,154	9,342,571	22,911	19,003	11,222	-
TOTAL	144,831	99,103	12,845	441,078	14,859,811	22,911	334,163	11,222	398,296
LAKE MICHIGAN									
U.S.	931,240	191,468	2,747,744	3,374,524	5,417,730	-	241,324	-	474,956
Canada	0	0	0	0	0	0	0	0	0
TOTAL	931,240	191,468	2,747,744	3,374,524	5,417,730	-	241,324	0	474,956
LAKE HURON									
U.S.	184,656	18,824	686,096	683,900	1,797,570	-	7,220	-	94,720
Canada	79,224	9,694	511,949	1,303,933	6,444,059	166,245	58,571	19,103	-
TOTAL	263,880	28,518	1,198,045	1,987,833	8,241,629	166,245	65,791	19,103	94,720
LAKE ERIE									
U.S.	572,316	206,528	2,189,144	1,794,940	1,439,360	-	35,484	-	129,796
Canada	65,926	23,284	1,182,228	670,031	342,187	8,029	23,438	2,884	-
TOTAL	638,242	229,812	3,371,372	2,464,971	1,781,547	8,029	58,922	2,884	129,796
LAKE ONTARIO									
U.S.	290,240	98,448	425,188	1,124,016	2,478,130	-	30,660	-	271,432
Canada	110,172	56,419	387,729	1,056,468	1,254,625	30,982	48,679	5,170	-
TOTAL	400,412	154,867	812,917	2,180,484	3,732,755	30,982	79,339	5,170	271,432
GREAT LAKES									
U.S.	2,117,324	610,684	6,058,776	7,367,304	16,650,030	-	629,848	-	1,369,200
Canada	261,281	93,084	2,084,147	3,081,586	17,383,442	228,167	149,691	38,379	-
TOTAL	2,378,605	703,768	8,142,923	10,448,890	34,033,472	228,167	779,539	38,379	1,369,200

* To convert from hectares to acres, multiply by 2.47

TABLE 6

LAND USE PROJECTIONS FOR THE GREAT LAKES BASIN
(Thousand Hectares) *

	U.S.	CANADA	TOTAL
1980			
Urban	3,054.3 (11.9)+	362.1 (2.3)	3,416.4 (10.8)
Agriculture	12,650.4 (-5.8)	3,796.5 (-26.5)	16,446.9 (-11.5)
Forest	15,788.2 (-5.2)	18,671.2 (7.4)	34,459.4 (1.3)
Other	1,941.0 (-2.9)	490.0 (17.8)	2,431.0 (6.6)
2000			
Urban	3,487.6 (27.9)	446.0 (2.6)	3,933.6 (27.6)
Agriculture	12,321.0 (-8.2)	3,497.4 (-32.3)	15,818.4 (-15)
Forest	15,684.3 (-5.8)	18,640.8 (7.2)	34,325.1 (0.8)
Other	1,941.0 (0)	736.6 (77.)	2,677.6 (10.9)
2020			
Urban	3,689.0 (35.2)	523.8 (48)	4,212.8 (36.7)
Agriculture	12,172.7 (-9.3)	3,325.1 (-35.6)	15,497.8 (-16.6)
Forest	15,631.2 (-6.1)	18,190.3 (4.6)	33,821.5 (-0.6)
Other	1,941.0 (0)	1,280.6 (208.)	3,221.6 (33.4)

+ Percentage change from current levels shown in parentheses

* To convert from hectares to acres, multiply by 2.47

SPECIALIZED LAND USES

Eight specialized land use categories are discussed in this report: (1) mine tailings disposal areas (Canada only); (2) liquid and solid waste disposal areas; (3) dredge spoil disposal; (4) deepwell disposal; (5) lakeshore and riverbank erosion; (6) intensive livestock operations; (7) high density non-sewered residential areas; and (8) recreational lands. These eight categories cover the more significant sources of pollution from land use activities affecting water quality of the Great Lakes.

Mine Tailings Disposal

The mine tailings disposal sites in the Great Lakes basin are concentrated in the northern portion, where most of the mining activity takes place. In the Canadian portion of the basin there are 37 active mine tailings disposal sites and 112 closed sites. Eleven of the active sites are found in the Lake Superior basin, 24 in the Lake Huron basin, and 2 in Lake Ontario.

In the U.S. portion of the basin, the most significant site is the Reserve Mining disposal site on the North shore of Lake Superior.

Liquid and Solid Waste Disposal

Land disposal of liquid waste has been used for some time as an alternative method for disposing of municipal and industrial effluents. This is accomplished by using the soil to filter the wastewaters and sludges applied to it. Impacts on water quality vary according to site characteristics. Potential pollutants are heavy metals, nitrogen (organic nitrogen, nitrate, and ammonia), phosphorus, other inorganic ions, toxic organic compounds, suspended solids and pathogens.

Solid waste is the most prominent of the land disposal operations. Many of these sites were not categorized as to the method of disposal. Therefore, it is difficult to determine what percentage of the total sites is relatively nonpolluting (sanitary landfills) and what percentage is potentially harmful to water quality (open dumps).

A summary of the liquid and solid waste disposal sites in the Great Lakes basin is presented in Table 7. There are a total of 4,078 sites, 442 in the Lake Superior basin, 1590 in the Lake Michigan basin, 839 in the Lake Huron basin, 672 in the Lake Erie basin and 535 in the Lake Ontario basin.

TABLE 7

WASTE DISPOSAL SITES IN THE GREAT LAKES BASIN

LAKE	UNITED STATES	CANADA	TOTAL
Superior	345	97	442
Michigan	1590	0	1590
Huron	379	460	839
Erie	514	158	672
Ontario	232	303	535
Great Lakes	3060	1018	4078

Future Trends in Disposal Operations

Four disposal operations--liquid waste, solid waste, dredge spoil and artificial fill, and deepwell disposal operations--form the major methods for allocating waste to the environment. Overall, the amount of wastes to be disposed of will increase in the future in response to population and economic changes. As will be seen, this relationship will vary according to the type of disposal procedure.

Liquid Waste Disposal

There are a variety of factors which will affect the future trend in utilizing land for the disposal of liquid effluents, both from municipal and industrial concerns. One of the possible limitations to expansion of liquid waste disposal operations is the amount of land required for this practice. At present the most suitable land for disposal is in agricultural uses. The agricultural interests would have to be satisfied before any additional land disposal could be carried out.

Conversely, if the costs of alternative disposal methods increase significantly, and if population and economic growth develops at a less rapid pace, then land treatment systems for liquid wastes may become an attractive option for many communities and small industrial concerns.

One particularly attractive aspect of liquid waste disposal operations is the ability to remove pollutants at a rate of efficiency not usually available without incurring exceptional costs with alternative disposal systems. In this sense land treatment systems are generally competitive on a cost-effectiveness basis to alternative disposal methods.

Liquid waste disposal practices, however, are limited by the variety of public concerns focusing on the perceived incompatibility of such practices with alternative land uses, especially residential activities. There are questions concerning the public health, social and economic impacts that land treatment systems may have upon adjacent areas. If public attitudes towards land treatment systems focus primarily on the potential adverse effects these systems can generate, this could limit the acceptability of these treatment systems.

Solid Waste Disposal

Three factors will affect future trends in solid waste disposal. First, per capita waste generation is unlikely to change significantly except as it is affected by the amount of disposable goods and materials generated in economic activities. Second, the number of waste disposal sites is likely to diminish as more counties convert to larger sanitary landfill operations. Finally, the amount of wastes disposed into the environment will be affected to some extent by the amount of materials recycled back into the economy.

The generation of solid wastes will increase in line with projected population trends. Per capita disposable income will increase with a possible tendency toward increasing amounts of solid wastes generated per capita. It is unlikely, however, that during the next 20 years per capita waste generation will increase significantly beyond current levels.

There is a general trend in the Great Lakes basin towards fewer, but larger and better-managed solid waste disposal sites. Small open dump sites are being closed throughout the basin as the waste is consolidated in larger sanitary landfill sites. One consequence of this policy, however, is that higher volume disposal sites may have several times the usual impact on water quality if they are not properly constructed and sealed. Thus, it is important to insure that these larger regional waste disposal sites are given proper engineering and environmental attention in their design and maintenance in order to prevent water quality degradation.

The recycling of waste materials is likely to decrease the volume of waste requiring disposal in the future. However, recycling so far has mainly revolved around reusing glass, paper, and metal materials and has not involved recycling of garbage or general refuse, which are the main producers of leachates. The recycling of reusable materials, therefore, is unlikely to affect the amount of leachates produced in sanitary landfill sites.

In addition, the closing of open dumps in the Great Lakes Basin in many instances has not involved the complete sealing of the abandoned sites. Rather, the policy has often been to abandon the open dumps with a modicum of cover, thereby leaving the site to produce leachates which can eventually infiltrate into ground and surface waters. It is likely that contamination from these closed dumps will continue and may even increase as refuse decays. Although over time the amount of leachates produced from closed sites will decrease as the materials decompose, it is unlikely that such a reduction in leachates will be achieved within the next 10 to 15 years. Attention to these problems is needed, perhaps by requiring open dumps to be properly sealed upon their abandonment to prevent leachate contamination of surface and ground waters.

<u>Dredge Spoil Disposal</u>

Because of population and industrial development in the Great Lakes Basin, some of the sediment that is removed by dredging activities has been polluted by municipal, industrial, and agricultural activities. Potential pollutants that are common to the affected sediments include nitrogen, phosphorus, organic matter, iron, oil and grease, mercury, lead and zinc. The average annual volume of dredge spoil disposal in the Great Lakes basin is 6.4×10^6 cubic metres (8.4×10^6 cubic yards). About 75% of these sediments are polluted and require confinement.

Future Trends in Dredge Spoil Disposal and Artificial Fill

Future trends in dredge spoil and artificial fill activities are dependent on several factors. It is assumed that maintenance dredging of harbours and channels is likely to continue at present rates. If larger locks are constructed, and larger ships will be utilizing the facilities, there will be a demand for deeper and wider harbours. This would require significant amounts of dredging and would increase the amount of dredge spoil in certain near-shore areas.

As economic development increases, there may be a further increase in the percentage of polluted sediments requiring confinement, assuming the present level of waste treatment.

Current policies to limit the amount of artificial fill and to preserve wetland and marsh areas along the shoreline of the Great Lakes continue to receive support from many quarters. However the desires of many lakeshore residents in the Basin to protect their waterfront properties from higher lake levels will increase pressures for more small artificial fill zones to prevent beach and shoreline erosion in residential and recreational areas.

Deepwell Disposal

There are about 100 deepwell disposal sites in the Great Lakes Basin.

Deepwell waste disposal techniques have been practised for decades, primarily for the disposal of brines produced in oil field operations. Since about 1950, deepwell disposal of industrial wastes has become an increasingly popular solution for elimination of toxic or noxious liquids. Most of the wastes injected are high-strength organics, caustics, acids or other toxic materials, and processed brines. These wastes are usually injected into strata several thousand metres deep, containing waters high in total dissolved solids; however, the formations act as storage reservoirs for wastes and should prevent contamination of other resources or areas. Most states now either do not permit, or have stringent requirements for new proposals because of the uncertainty of potential geologic impacts.

Ideally, the receiving formation is bounded both above and below by formations of low vertical permeability. Even with such precautions, upward flow can occur if high injection pressures are used and hydrofracturing has occurred.

Future Trends in Deepwell Disposal

Future trends in the use of deepwell disposal vary greatly throughout the Great Lakes Basin. Some Lake basins have no such operations at the present time because of unsuitable geological formations and will have none in the future, while other Lake basins have many such disposal operations and their number will continue to grow in the future depending upon government attitudes, the administration of legal controls, and the success of existing disposal operations.

There have been problems with the use of this disposal method, primarily because of unknown and abandoned test wells and holes that penetrate the major injection zone. Fluid discharge through these open holes to the surface, or flow into shallow ground-water aquifers, present problems. Future deepwell injection problems have the greatest potential for occurrence in the State of Michigan.

Erosion

Erosion along the land-water interface occurs in two particular areas - lakeshore and riverbank zones. Lakeshore and riverbank erosion contribute sizeable amounts of sediment into the nearshore area. However, most of this sediment does not contain nutrients or pesticide materials, and therefore its major effect on surface waters is in increasing nearshore turbidity and the smothering of benthic biota.

Other types of erosion include sheet, rill, and small gully erosion which occur on upland areas. Sediment, plant nutrients, and pesticide materials may be transported to streams, inland lakes, and the Great Lakes as a result of these forms of erosion.

Lakeshore Erosion

Three major factors control the amount of erosion on Great Lakes shorelines: (1) physical characteristics of the shoreline (Table 8); (2) the combination of lake levels and storm intensity and frequency; and (3) shoreline land use.

There are an estimated 664 kilometres of critical erosion areas on the Great Lakes (Table 9) as calculated on the basis of damage or severe erosion rates.

Riverbank Erosion

Riverbank erosion can be caused by direct abrasion, undercutting, or sloughing, or by a combination of these processes. It is a natural geologic phenomenon by which valley development occurs as a result of gradual widening. Existing flood plain and land along the valley sides are lost or altered by lateral cutting and undermining. Serious damages can also result when man's activities accelerate this natural process.

TABLE 8

GREAT LAKES SHORE TYPES
(Kilometres)*

TYPE OF SHORE	LAKE SUPERIOR (1)	LAKE MICHIGAN	LAKE HURON (2)	LAKE ERIE	LAKE ONTARIO	GREAT LAKES
Artificial Fill	9.8	107.8	6.6	163.0	63.2	350.4
Erodible High Bluff	95.2	437.8	164.9	417.6	120.0	1235.5
Non-Erodible High Bluff	360.3	75.0	156.1	3.2	24.6	619.2
Erodible Low Bluff	411.2	190.2	140.9	201.4	363.5	1307.2
Non-Erodible Low Bluff	272.2	39.5	168.4	11.4	225.1	716.6
Beach-Dune Complex	130.6	340.8	234.1	237.0	78.8	1021.3
Erodible Low Plain	98.7	460.0	332.0	122.3	199.6	1212.6
Non-Erodible Low Plain	37.4	277.6	254.4	5.3	14.5	589.2
Wetlands	43.8	250.4	490.6	187.9	119.3	1092.0
Total Shore	1,459.2	2,179.1	1,948.0	1,349.1	1,208.6	8144.0

(1) U.S. portion only

(2) U.S. Portion and Canadian portion from Sarnia to Port Severn

* To convert from kilometres to miles, multiply by 0.63

TABLE 9

CRITICAL SHORELINE EROSION AREAS
ON THE GREAT LAKES
(Kilometres)*

LAKE	UNITED STATES (1)	CANADA (2)	TOTAL
Superior	46.2	0	46.2
Michigan	210.0	0	210.0
Huron	12.9	70.0	82.9
Erie	33.1	154.0	187.1
Ontario	27.0	111.0	138.0
Great Lakes	329.2	335.0	664.2

(1) Critical when considering economic impact; water quality impacts have yet to be determined.

(2) Areas with severe erosion rates, i.e. greater than 0.5 $m^3/m/m/yr$ (cubic metres per metre of bluff height per metre of shoreline per year).

* To convert from kilometres to miles, multiply by 0.63.

In the United States portion of the basin, approximately 13,000 kilometres (7,800 miles) of stream banks are experiencing moderate erosion and 4,000 kilometres (2,400 miles) are undergoing severe erosion.

Erosion in the Future

Erosion is fundamentally a natural process that occurs to some degree on all shorelines. Among the natural factors affecting erosion on the Great Lakes are non-tidal fluctuations in water level, wave action, ice action, physical characteristics of the shoreline, and supply of littoral materials. These natural factors are largely uncontrollable and unpredictable. Man-induced factors have a smaller effect on the erosion process and include settlement, agriculture, construction on the shoreline, commercial sandmining along the shoreline and in nearshore areas, and shipping activities. These man-induced factors can be controlled through shoreland planning and management strategies based on a knowledge of the erosion process.

Lakeshore and riverbank erosion in the Great Lakes basin are generally expected to remain near the present levels on the average for the next 10 to 15 years. If management strategies are implemented, erosion could show a moderate decline in the near future.

Intensive Livestock Operations

In recent years attention has been given to the water quality problems caused by agricultural wastes due to changes primarily in agricultural production practices. For economic reasons, livestock production has become increasingly concentrated in larger operations.

Table 10 contains statistics on intensive livestock operations in the Great Lakes basin. For the United States portion of the basin, intensive livestock operations were defined as follows: 10,000 or more poultry; 100 or more cattle; and 200 or more swine. For the Canadian portion, the definitions were: 30,000 or more poultry; 75 or more dairy cattle; 150 or more beef cattle; and 300 or more swine. Based on these criteria there are 14,800 intensive livestock operations in the Great Lakes basin.

Future Trends in Intensive Livestock Operations

Over the next 15 years, there will be a trend towards larger and more intensive animal feedlots and a continued decrease in small live-

TABLE 10

INTENSIVE LIVESTOCK OPERATIONS IN THE GREAT LAKES BASIN

LAKE	Poultry U.S.	Poultry CANADA	Poultry TOTAL	Cattle U.S.	Cattle CANADA	Cattle TOTAL	Swine U.S.	Swine CANADA	Swine TOTAL	TOTAL
Superior	3	-	3	84	-	84	3	-	3	90
Michigan	280	-	280	5,094	-	5,094	1,477	-	1,477	6851
Huron	51	27	78	704	159	863	98	111	209	1150
Erie	206	78	284	1,816	711	2,527	1,145	546	1,691	4502
Ontario	98	60	158	1,696	132	1,828	44	177	221	2207
Great Lakes	638	165	803	9,394	1,002	10,396	2,767	834	3,601	14,800

stock operations in the Great Lakes Basin. This trend will result from the increased profitability and effectiveness that larger livestock operations provide over smaller ones. Livestock operations, therefore, will increasingly come to be viewed as commercial operations rather than as small rural ventures. Consequently, waste production from these feedlots will tend to be concentrated in particular locales. Waste disposal systems will need to be maintained for water quality.

High-Density, Non-sewered Residential Areas

Growth of individual family residences in developments in rural areas surrounding population centers has increased in recent years. Many of these utilize individual sewage disposal systems, usually consisting of septic tank - ground absorption systems. These systems can do an adequate job of treating home sewage except in those areas which have soil with poor absorptive capabilities and/or high seasonal water tables. The latter conditions cause system failure resulting in the discharge of inadequately treated sewage to local ditches, streams and lakes.

Table 11 contains an estimate of the housing units and population within high density, non-sewered residential areas in the Great Lakes basin. The population living in high density, non-sewered residential areas (7,114,916) represents 20 percent of the total Great Lakes basin population. The population in the U.S. portion of the Basin that is in high-density - non-sewered residential areas is, in fact, greater than the <u>entire</u> Canadian population in the Basin.

No attempt has been made to distinguish between those housing units or areas which have properly operating systems and those which don't. Correction of problems in existing areas and prevention of problems in future developments is a socio-economic problem which needs to be addressed.

Future Trends in High-Density, Non-sewered Residential Areas

Households with on-site sewage disposal systems are projected to continue at about the same percentage of the total housing stock. This projection is based on the assumption that future population growth will continue present patterns. Further growth will occur in urban areas with municipal sewage systems. Urban growth will be balanced by continued growth in rural and semi-rural areas, where development of municipal sewage treatment facilities will be economically difficult.

With improved on-site sewage disposal technologies and an enhanced ability for on-site systems to dispose of household effluent in an environmentally sound manner, the utilization of such on-site disposal

TABLE 11

HIGH-DENSITY, NON-SEWERED RESIDENTIAL AREAS IN THE GREAT LAKES BASIN

Lake	Housing Units			Population		
	U.S.	CANADA	TOTAL	U.S.	CANADA	TOTAL
Superior	54,760	2,357	57,117	191,660	8,250	199,910
Michigan	766,083[1]	0	766,083	2,681,290	0	2,681,290
Huron	189,663	68,487	258,150	663,820	239,704	903,524
Erie	580,203[1]	54,876	635,079	2,030,710	192,066	2,222,776
Ontario	240,769	75,636	316,405	842,691	264,725	1,107,416
Great Lakes	1,831,478	201,356	2,032,834	6,410,171	704,745	7,114,916

[1] Because data are by counties, actual units within Great Lakes Basin boundaries should be decreased by about 18 percent.

could increase. Such technology, however, is not expected to significantly affect the amount of nonsewered housing in the near future. Likewise, the expansion of sewage treatment plant facilities currently is limited by the costs involved with providing secondary and tertiary treatment. Since many plants are currently overburdened in terms of their capacity to adequately treat the volume of wastes already collected, the major investment in municipal treatment will continue to be concerned with sewage treatment facilities rather than on improving the collection of municipal wastes. Continued development of recreational homes in the northern portions of the Great Lakes Basin will be associated with the development of individual septic tank systems.

Recreational Land Use

The Great Lakes basin possesses diverse and outstanding natural features: Great Lakes water surface and shoreline, thousands of inland lakes and associated beaches, mountains and rolling morainic hills, extensive forests, streams and marshland with relatively high-quality waters, and many islands, inlets, and bays. While a few of these resources are near the large urban centres in the southern portion of the basin, most are located in the drainage areas of Lake Superior and the northern parts of Lake Michigan and Huron. In general, one of the most critical needs for recreation in the Basin is the provision of high capacity day use and weekend use facilities close to major metropolitan areas. Accessibility to all city residents must also be provided. The shoreline and islands of the Great Lakes offer great opportunity for recreation, but a constant effort is needed to prevent industrial, commercial, and private ownership from restricting public access to the regional land and water resources.

Table 12 gives information on these areas which now provide or have greater potential for providing recreational opportunities in the Great Lakes basin. It should be noted that these sites also have the potential to create water quality problems through the poor waste treatment and excessive erosion which often accompany intensive use.

TABLE 12

RECREATIONAL AREAS IN THE GREAT LAKES BASIN
(Hectares)*

LAKE	UNITED STATES	CANADA	TOTAL
Superior	574,472	22,911	597,383
Michigan	629,584	0	629,584
Huron	182,048	166,245	348,293
Erie	205,276	8,029	213,305
Ontario	156,720	30,982	187,702
Great Lakes	1,748,100	228,167	1,976,267

* To convert from hectares to acres, multiply by 2.47

Future Trends in Recreational Lands

Recreational activities in terms of user days are likely to more than double by 1990. Growing populations in the more urbanized southern areas of the Great Lakes Region will be an important source of demand. In conjunction with expanded use of the recreational facilities in the Basin will come an intensification of existing facilities usage, increasing the pressure upon available facilities to handle the waste generated by tourists.

With the expansion of recreational activities, there will be an increase in the amount of both liquid and solid waste to be disposed of. In addition, the construction of recreational second homes in rural areas will lead to an increase in amounts of nonsewered housing in these areas. Since recreational pursuits are seasonal, the major impacts from recreational activities will occur in the summer months. However, increasing enjoyment of winter activities such as skiing and snowmobiling has meant an increase in year-round use.

The specific impacts and the magnitude of the impacts resulting from recreational pursuits has not been well documented in the past. Given the likelihood that these activities will increase in the future, more work needs to be done in this field to determine the magnitude of impact on the Great Lakes Basin.

MATERIALS USAGE INVENTORY

The objective of the inventory of present materials usage was "to provide an inventory of various materials applied to land which may influence the quality of drainage water". The materials identified for inclusion in this inventory were: agricultural pesticides; commercial fertilizers; agricultural manure; lime; and road salts.

The results of the inventory are presented in Table 13. Lake Erie ranks first in the usage of pesticides and nutrients from agricultural manures and fertilizers. The largest amount of lime is used in the Lake Michigan basin, nearly half of the total. More road salt is used in the Lake Ontario basin than in any other lake basin; a million tons annually.

A more comprehensive Materials Usage Inventory was prepared by the Great Lakes Basin Commission and is contained in a report available from the IJC Regional Office, Windsor.

Materials Usage Trends

In projecting materials usage (Table 14) it should be pointed out that agricultural developments are directly affected by population trends, national and international economic conditions, environmental attitudes, and national agricultural decisions about food production. Changes in any one of these variables will significantly alter any agricultural projection. In addition, technological changes in the types of materials used in agricultural practices can significantly alter the influence these materials may have on water quality. Therefore, it is difficult to accurately project the influence of agricultural practices upon water quality in the future. For the sake of clarity, this section assumes that major influences will remain relatively stable and that there will be no major shifts in agricultural production practices within the next 10 to 15 years, either in terms of technology or in terms of crop types.

Agricultural Chemicals

Several trends indicate an increased usage of agricultural chemicals over the next 10 to 15 years. With continued rising labor costs, the use of agricultural chemicals to control weeds and pests, as well as various forms of fungi and bacteria, will continue to be economically attractive in many agricultural operations. The use of chemicals on crops will therefore continue at current or higher rates in the Great Lakes Basin in the near future.

TABLE 13

ESTIMATED ANNUAL MATERIALS USAGE IN THE GREAT LAKES BASIN
(Metric Tonnes)

	NUTRIENTS FROM MANURE & FERTILIZERS	LIME	PESTICIDES	ROAD SALTS
LAKE SUPERIOR				
United States	21,042	28,895	140	59,804
Canada	3,630	N.D.	0.5	28,428
TOTAL	24,672	28,895	140.5	88,232
LAKE MICHIGAN				
United States	810,325	623,459	9,356	594.694
Canada	0	0	0	0
TOTAL	810,325	623,459	9,356	594,694
LAKE HURON				
United States	185,928	25,714	1,845	95,583
Canada	180,118	N.D.	857	274,183
TOTAL	366,046	25,714	2,702	369,766
LAKE ERIE				
United States	590,407	459,377	6,410	489,075
Canada	275,967	N.D.	3,703	206,822
TOTAL	866,374	459,377	10,113	695,897
LAKE ONTARIO				
United States	209,287	175,656	2,701	305,114
Canada	90,330	N.D.	801	741,620
TOTAL	299,617	175,656	3,502	1,046,734
GREAT LAKES				
United States	1,816,989	1,313,101	20,452	1,544.270
Canada	550,045	N.D.	5,362	1,251,053
TOTAL	2,367,034	1,313,101	25,814	2,795,323

N.D. - not determined

TABLE 14

TRENDS IN MATERIALS USAGE
GREAT LAKES BASIN
(Metric Tonnes)

	1972	1980	1990
Agricultural Chemicals			
Herbicides	14,715	15,821	16,933
Insecticides	7,396	7,426	7,250
Fungicides	3,635	3,826	4,038
Nutrients from Manure	950,072	973,824	997,576
Nutrients from Fertilizers	1,416,962	1,570,890	1,817,869
Lime	1,313	1,313	1,313
Road Salt	2,795,323	3,084,900	3,380,520

One factor, however, which may tend to decrease the rate of growth in the use of chemicals on crops is the impact these chemicals may have on water quality. It is becoming increasingly apparent that the use of chemicals on crops deposits residues which can infiltrate into ground and surface water areas, and that residues from certain chemical compounds can enter into the food chain and threaten to produce potentially disruptive influences to higher forms of life.

Concerning specific chemicals, it is projected that herbicide usage may increase about 15 percent by 1990. Since herbicides replace a significant amount of man-hours devoted to weed control, there is a strong incentive to continue their use at current or higher levels into the future. Fungicide use may increase about 5 percent by 1980 and another 5 percent by 1990. Insecticide use is expected to increase slightly to 1980 and decrease after that.

Although the use of chemicals on crops is likely to increase over the next 10 years, the water quality impact of these chemicals is not so clear. One of the major concerns in using chemicals is the amount of residue remaining which can enter ground and surface water areas. In the case of herbicides that is known as carry-over, and in the case of insecticides as persistence. It is believed that the persistence associated with insecticides will be almost entirely eliminated in the next 10 years, and the carry-over in herbicides will be greater reduced, if not entirely eliminated as new forms of chemicals with little or no residue generation replace the current stock of chemical types now used.

This is not to say that water quality impacts will be eliminated from the use of chemicals on crops, but that with increasing use of chemicals, a shift is likely towards less noxious forms of chemicals, mainly those which produce less residue.

Agricultural Manures

Livestock numbers are projected to remain relatively stable in the Great Lakes Basin and will increase slightly overall. Some Lake basins will have a slight increase in overall livestock numbers, while others will have a slight decrease. The amount of manure produced from various livestock types will remain near current levels, with an overall total increase of about 5 percent by 1990.

However, there are trends toward more intensive livestock operations, which will have the effect of increasing the impact of manures in specific locales. Assuming proper construction and maintenance techniques, the discharge of animal wastes should not adversely affect water quality. Without preventive measures, it is quite possible that certain reaches of ground and surface waters can be contaminated via animal wastes. Specifically, large amounts of nitrogen and phosphorus compounds can be leached into the soils from intensive livestock operations, due to the corresponding increase in the concentration of wastes.

Commercial Fertilizers

Commercial fertilizer usage rates are expected to increase moderately in the Great Lakes Basin - about 1.4 percent per year. The greatest increase will be in nitrogen, with lesser increases in potash, and with phosphorus tonnage rates remaining about the same or declining slightly. In either event, there is likely to be a shift towards liquid fertilizers due to their ease of application.

It should be pointed out that trends in agricultural crop production indicate a move towards more intensive cultivation, and it is therefore likely that commercial fertilizer usage will increase in more intensely cultivated areas. Higher concentrations of fertilizers in particular areas may increase drainage of nutrients to ground and surface waters.

Lime (U.S. Portion of the Basin only)

Despite projections by the National Limestone Institute for increased needs for liming materials, lime rates will probably remain at current levels. Therefore water quality impacts resulting from liming will tend to remain unchanged, except in instances where agricultural crop production has intensified. If lime is used more intensely in these instances, it may affect ground and surface waters.

Road Salts

Several trends in the Great Lakes Basin will likely require increased use of salts to prevent road icing in winter months. Bare pavement policies will be demanded by the public for major highways. Growth in major roadway mileages will increase the amounts of salts needed to prevent icing during winter months.

However, there are also trends toward limiting salt applications. Due to increased salt prices, there will be an incentive to provide secondary and minor road systems with lesser amounts of salts. The rate of salt application may actually decrease in these secondary road systems.

Road de-icing salts affect ground and surface waters through chloride discharges which can, over time, affect the salinity of nearby wells and open water areas. There are efforts toward more efficient salt applications and the prohibition of salting in areas where ground water and aquifers which supply drinking water to nearby residences could be contaminated.

In general, while salting will be continued on major road systems at current application rates, there will likely be a decrease in the amounts of salt used on secondary and minor road systems. In balance, the overall amounts of salts applied will probably increase gradually over time, although they will be applied in a more selective fashion.

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